FRONTAL PASSAGES OVER THE NORTH ATLANTIC OCEAN

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ABSTRACT

Graphical and tabular data on the frequency of frontal passages at Ocean Station Vessels on the North Atlantic are compiled from historical weather maps for the years 1945–57. The stabilizing influence of the Gulf Stream is shown by the rapid modification of air temperature at all stations and by the rapid transition of frontal systems. The greatest frequency of fronts is found at the line of initial contact of cooler air with that associated with the Gulf Stream in the westernmost region of the ocean.

The value of the historical sea level synoptic weather maps as a data source for the climatological study of atmospheric motion systems is emphasized.

1. INTRODUCTION

The air mass theory of modern meterology was offered by Bjerknes [1] in 1919. Bjerknes's concept, though modified over the years, continues as a basic approach to the analysis of daily surface or "sea level" synoptic weather maps [7]. The boundaries or leading edges of air masses, generally known as "fronts," are regularly entered on surface weather maps. Because fronts often produce notable weather changes as they pass by an individual location, the past, present, and anticipated positions of fronts bear heavily on the daily weather forecast.

Fronts, air masses, and other dynamic features of the general circulation, presently indispensable to daily weather map analysis and forecasting, are also useful in explaining climate in qualitative terms. These features are not, however, so amenable to statistical analysis of climate. Air masses particularly are subject to labeling that differs among analysts. Likewise the placement of fronts on a weather map is subject to individual interpretation. As a result, there have been but few efforts to analyze these features systematically as climatic elements. However, the careful preparation of an historical series of daily weather maps offers a far greater potential for consistency and continuity than those prepared on an operational basis.

The program for preparing the first series of such maps during World War II [11] and some of their derivatives (many still unpublished) was reported by Wexler and Tepper [16]. During the war, as the first 10 years of the series became available (1929–38), a great many statistics on fronts, cyclones, anticyclones, deepening and filling and tracks of Lows, etc. [2, 3, 13, 14, 15] were compiled. A

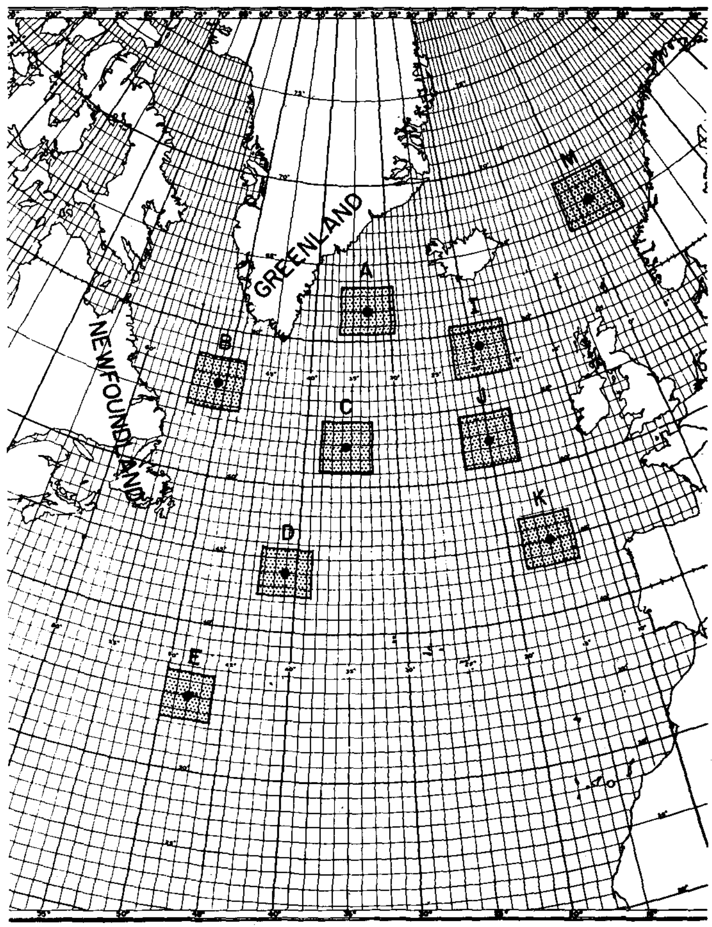

FIGURE 1.—Presently assigned Ocean Station Vessel positions in the North Atlantic, with position center point circumscribed by "on-station" limits. These are the areas used in tabulating frontal passages.

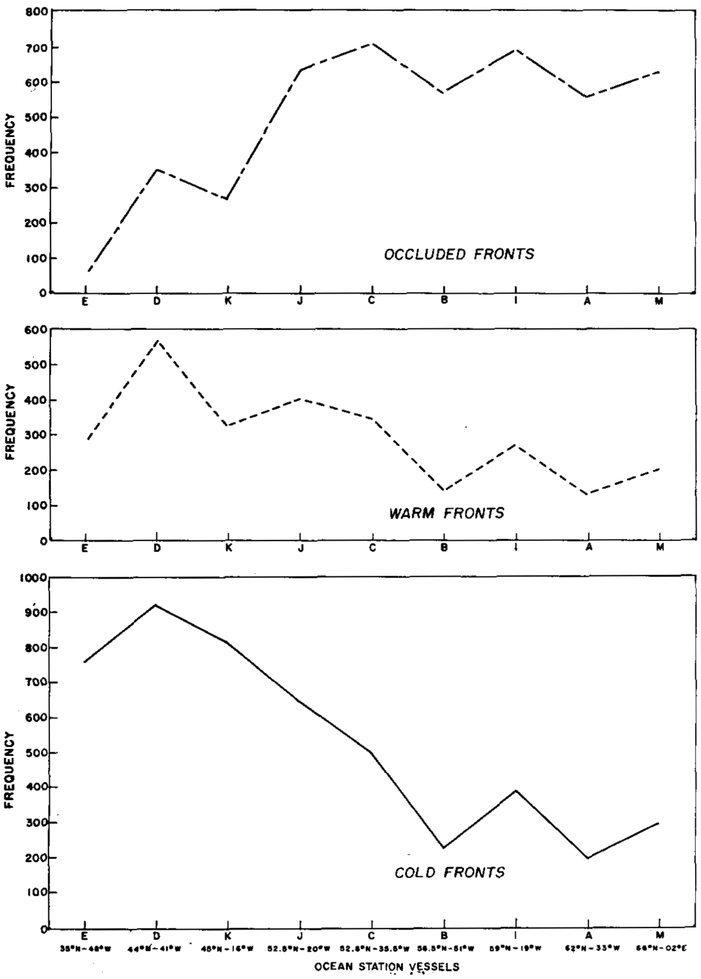

FIGURE 2.—Total frequency of major frontal passages at North Atlantic Ocean Station Vessels for the period October 1945–June 1957. Stations are arranged to show the latitudinal progression of fronts as well as areas of maximum and minimum frequency.

summary of some of these data was later published [12] by the U.S. Navy under whose sponsorship the work of compilation had been done. Other examples of the utility of such maps are the work of Gregor and Krivsky [4] and Klein [5].

The purpose of this paper is to present a summary of frontal systems from the sea level charts of the more recent years in the map series [9, 10] for a portion of the North Atlantic Ocean frequently traversed by both ships and aircraft.

2. DATA

Eleven years and nine months (October 1945 through June 1957) of sea level maps are used as source material [6]. These maps are published for the 1230 GMT surface synoptic observations; i.e., at 24-hour intervals. Generally only major fronts are drawn on the maps. For the most part minor fronts do not appear unless uniquely significant. Beyond the scope of analysis in the historical series are occasional redevelopments or frontolyses which take place within the 24 hours. Nevertheless the consistency that is maintained in this historical series of maps permits relatively systematic climatological treatment. Reference points for compiling the frontal frequencies discussed here are those locations presently assigned in the North Atlantic Ocean Station Network (see fig. 1), although vessels have not been located at these exact positions all through the period used. By the use of plastic masks, upon which the Ocean Station Vessel positions and "on-station squares" were printed in the correct scale, the fronts could be followed from day to day through the station squares. Checks were employed to guard against tabulating errors.

The following frontal types were considered: cold, warm, occluded, and stationary. An attempt to discriminate between cold and warm occlusions was abandoned because of the relative paucity of ship's observations. Data for stationary fronts are not presented separately, but are included in the graphs for all fronts combined.

Type of front and date of frontal passage at each Ocean Station Vessel position were recorded along with the

TABLE 1.—*Monthly frequency of frontal passages at Ocean Station Vessels by frontal type, for the period October 1945–June 1957*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Cold Fronts											
A	28	16	23	16	14	8	12	11	18	16	22	13
B	17	18	17	15	18	16	27	19	28	25	14	16
C	48	36	32	43	33	33	56	35	45	48	46	48
D	80	72	71	84	79	82	66	76	86	68	62	93
E	94	88	111	72	64	32	14	18	41	68	64	88
I	46	28	43	38	33	21	21	16	26	40	40	33
J	69	47	47	60	46	48	47	50	48	57	55	74
K	81	64	48	68	69	62	49	75	78	69	70	80
M	27	19	48	34	22	17	14	17	23	30	21	28
	Warm Fronts											
A	16	14	14	12	4	5	10	6	15	9	17	10
B	9	12	7	6	7	10	30	9	19	11	10	13
C	40	20	19	31	14	28	50	28	24	23	34	33
D	49	35	45	60	51	54	45	57	50	35	33	55
E	31	42	40	31	18	15	4	4	9	26	30	32
I	32	19	27	22	22	10	19	10	18	27	26	34
J	47	29	32	37	26	36	36	33	27	23	32	43
K	44	33	24	20	23	23	12	42	29	21	26	24
M	21	11	32	21	13	10	5	7	16	24	19	20
	Occluded Fronts											
A	50	39	51	47	55	38	31	45	32	60	45	64
B	45	35	33	45	42	48	43	53	55	69	61	44
C	68	57	59	61	65	59	38	55	49	70	58	75
D	47	42	51	31	40	16	5	5	15	29	33	38
E	10	10	5	8	3	1	0	0	0	1	4	9
I	78	47	51	61	43	62	55	50	47	72	48	78
J	71	51	45	52	48	53	45	46	52	54	54	66
K	34	21	36	18	23	23	14	11	18	20	25	27
M	64	47	48	76	37	34	45	33	49	68	56	74
	Stationary Fronts											
A	0	6	3	4	0	3	1	1	5	2	2	1
B	0	0	4	1	2	2	4	7	3	3	2	0
C	4	7	3	3	0	0	2	1	3	6	2	2
D	6	6	7	11	2	8	9	11	8	10	3	9
E	5	3	7	7	10	7	1	3	10	12	9	11
I	2	5	4	2	3	4	1	1	2	3	1	0
J	2	2	7	2	4	3	4	2	2	5	5	1
K	7	4	4	4	2	5	3	1	3	6	4	6
M	3	2	4	3	2	5	0	4	4	3	1	1

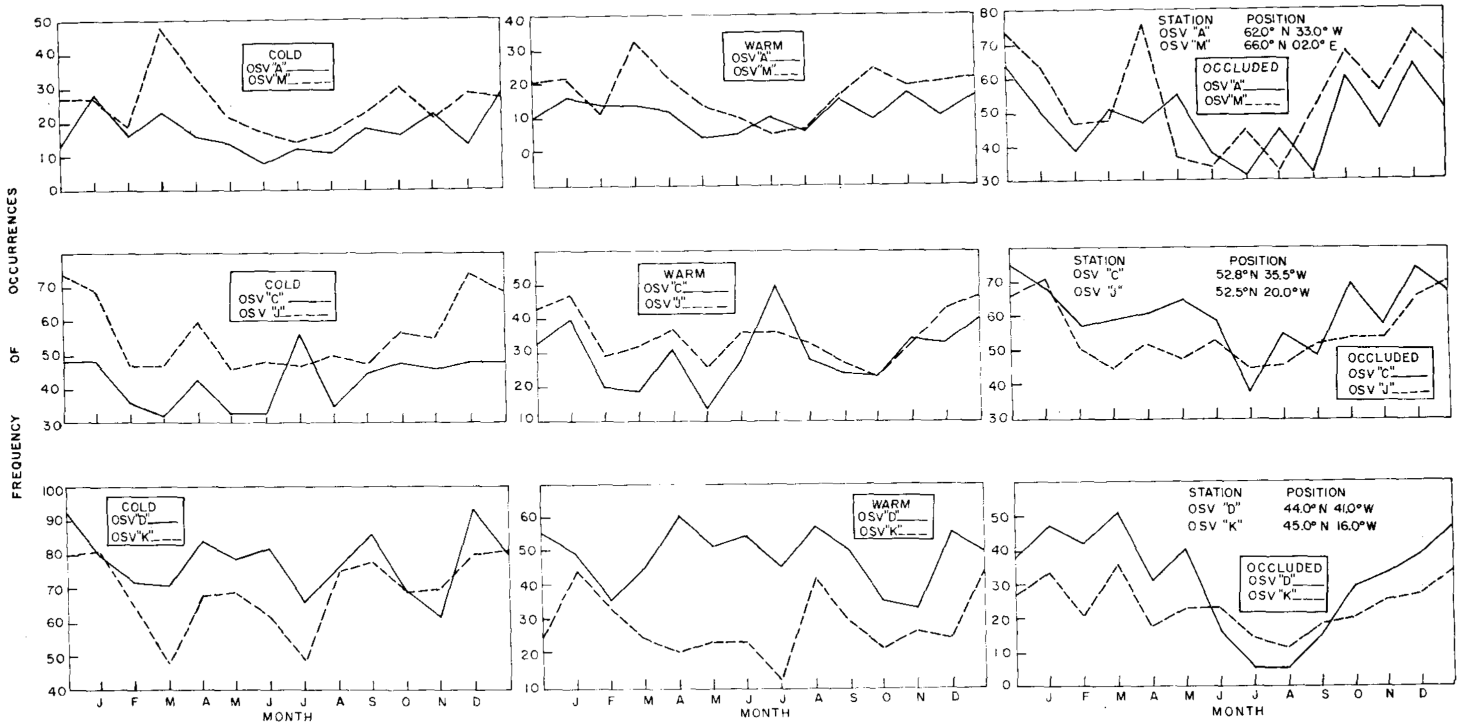

FIGURE 3.—Comparison of frequency of frontal passages at North Atlantic Ocean Station Vessels located in the same latitudinal zone for the period October 1945–June 1957.

affected station's temperature, dew point, pressure, and wind for the day before, the day of, and the day following frontal passage. Summaries of the data are presented in tables 1–4 and figures 2–7. Actual frequencies rather than percentage frequencies are shown so that contrasts between locations may be more sharply delineated.

During the period of 11 years and 9 months, there were 12,295 major frontal passages at the Ocean Station Vessel positions in the North Atlantic, or an average of 116.3 passages per station per year.

TABLE 2.—*Monthly total frequency and average frequency of frontal passages (all types) by station and month for the period October 1945–June 1957*

Stations		January	February	March	April	May	June	July	August	September	October	November	December
A	Total	94	75	91	79	73	54	54	63	70	87	86	88
	Average	8	6	8	7	6	5	5	6	6	7	7	7
B	Total	71	65	61	67	69	76	104	88	105	108	87	73
	Average	6	5	5	6	6	6	10	8	10	9	7	6
C	Total	160	120	113	138	112	120	146	119	121	147	140	158
	Average	13	10	9	12	9	10	13	11	11	12	12	13
D	Total	182	155	174	186	172	160	125	149	159	142	131	195
	Average	15	13	15	16	14	13	11	14	15	12	11	16
E	Total	140	143	163	118	95	55	19	25	60	107	107	140
	Average	12	12	14	10	8	5	2	2	6	9	9	12
I	Total	158	99	125	123	101	97	96	77	93	142	115	145
	Average	13	8	10	10	8	8	9	7	9	12	10	12
J	Total	189	129	131	151	124	140	132	131	129	139	146	184
	Average	16	11	11	13	10	12	12	12	12	12	12	15
K	Total	166	122	112	110	117	113	78	129	128	116	125	137
	Average	14	10	9	9	10	9	7	12	12	10	10	11
M	Total	115	79	132	134	74	66	64	61	92	125	97	123
	Average	10	7	11	11	6	6	6	6	8	10	8	10

3. FREQUENCY BY STATION

Outbreaks of cold air move farthest south behind cold fronts in the westernmost region of the ocean area. Generally upon reaching the vicinity of the Gulf Stream the southward movement is arrested. The predominant

TABLE 3.—*Extreme frequencies of frontal passages by station and type for the period October 1945–June 1957*

Station	Type	Highest frequency		Lowest frequency	
		Month	Frequency	Month	Frequency
A	Cold	January	28	June	8
	Warm	November	17	May	4
	Occluded	December	64	July	31
B	Cold	September	28	November	14
	Warm	July	30	April	6
	Occluded	October	69	March	33
C	Cold	July	56	March	32
	Warm	July	50	May	14
	Occluded	December	75	July	38
D	Cold	December	93	November	62
	Warm	April	60	November	33
	Occluded	March	51	July, August	5
E	Cold	March	111	July	14
	Warm	February	42	July, August	4
	Occluded	January, February.	10	July, August, September.	0
I	Cold	January	46	August	16
	Warm	December	34	June, August	10
	Occluded	January, December.	78	May	43
J	Cold	December	74	May	46
	Warm	January	47	October	23
	Occluded	January	71	March, July	45
K	Cold	January	81	March	48
	Warm	January	44	July	12
	Occluded	March	36	August	11
M	Cold	March	48	July	14
	Warm	March	32	July	5
	Occluded	April	76	August	33

TABLE 4.—*Frequency of intervals between frontal passages for the period October 1945–June 1957*

Number of days	Ocean station vessels								
	A	B	C	D	E	I	J	K	M
Less than 1	70	87	196	329	151	163	250	167	128
1	217	171	403	591	238	346	504	376	328
2	164	178	333	423	236	282	377	322	245
3	124	130	257	273	181	206	229	215	137
4	79	95	137	157	110	116	145	121	92
5	49	88	94	88	75	80	80	84	52
6	37	51	44	63	52	36	53	43	46
7	30	36	30	24	35	37	24	33	28
8	23	28	29	12	27	35	20	26	24
9	21	15	18	5	17	19	17	11	23
10	14	22	8	4	20	15	9	12	14
11	9	14	13	5	7	6	11	6	17
12	11	13	2	3	8	12	8	9	9
13	10	9	7	3	5	4	6	11	15
14	6	11	1	3	6	1	6	6	11
15	4	8	1	1	4	5	3	4	5
16	3	5		3	2	2	2	4	7
17	5	5	1			2	2	2	2
18	6	1	1		4	4		3	1
19	7	2		1		3		3	
20	3	4	1		1			1	1
21	4	2				1			
22	6	2			1	3		1	
23	5	1	1		1	2			3
24	1	2	2		1	2		1	1
25	5	1	1						5
26	1				1			1	3
27	4							1	1
28								1	1
29		1							
30	1				1	1			
31					1			1	
32		1					1		
33					1				1
35	1	1							
36	2		1						
37									1
38		1			1				
39					1				
40									1
41	1	1							
43					2				
44					1				
45		1							1
49					1				
54	1					1			
60					1				
63	1								
66									1
75					1				

frontal zone then parallels the northeastward course of the Gulf Stream flow.

Tables 1 and 2 indicate that Station "D" at 44.0° N., 41.0° W. experiences the highest frequency of frontal passages, all types of fronts considered. Schumann and van Rooy [8] also show the greatest frequency in this area of the oceanic region. This station also shows a maximum of 919 cold frontal passages and 569 warm frontal passages (fig. 2). It is situated in about the mean annual position of the polar front in the area where the Labrador current meets the Gulf Stream. Most occluded frontal passages occurred at Station "C," to the northeast at 52.8° N., 35.5° W.

Stations "A" and "B," although having the lowest frequency of total frontal passages (tables 1 and 2), display a feature of the Icelandic Low by their relatively high proportion of occluded frontal passages (fig. 2). Stations "I," "J," and "M" are similarly influenced, while "K," farther to the south, shows a high incidence of cold frontal passages. Station "E," the southernmost station, also has a high proportion of cold frontal passages in comparison to other types. These features are also reflected in the extreme frequencies (table 3).

Table 4 gives the frequency of intervals between frontal passages. The longest period on any station without a major frontal passage occurred on Station "E". On June 20, 1951, a cold front passed the station. The Bermuda High blocked any further southward movement of fronts in the vicinity of this station until September 3, 75 days later, when another cold front finally passed the station. Station "D" has the most rapid exchange of air masses. Intervals of from less than 1 day to 2 days between frontal passages are common.

4. FREQUENCY BY YEAR AND SEASON

The year of highest frequency of frontal passages was 1953 with a total of 1,213 fronts. The lowest frequency occurred in 1947 with 845. The season showing the greatest frequency was October, November, and December for all years studied except 1946, 1949, and 1950 when January, February, and March displayed the highest frequency. January showed the greatest frequency of any single month and July the least. Most cold and warm frontal passages occurred in January and most occluded frontal passages in December. The least number of cold and warm fronts occurred in the month of May, while July proved to be the month of fewest occlusions.

Figure 3 compares stations at approximately the same latitude in the eastern and western regions of the Atlantic. The modifying effects of the warm and cold stream circulations on the overlying air are easily seen. Stations "D" and "K" show the greatest contrast in warm frontal passages. At station "K" the Gulf Stream has become so diffused and mixed in its path across the Atlantic that it has now lost most of its identifying characteristics and is itself beginning its southward flow along with the cold air on the eastern part of the Atlantic. A sharp contrast in frequencies of frontal passages at high and low latitude stations is shown in figures 4 and 5. These graphs show the transition of frontal systems due to the effects of the Gulf Stream. Moving northward a great deal of the modified air is caught in the flow around the Icelandic Low.

A frequency distribution of the temperature differences of the day before the frontal passage and the day following for a sample of 6,820 fronts on all stations was computed (fig. 6). Temperature data for cold, warm, occluded, and stationary fronts were combined for this study. Temperature of the air was modified so rapidly that the mean 48-hour temperature change was near zero. In other words, on the average the temperature at 1230 GMT the day following the frontal passage had returned to about the same value as that of the day before the frontal passage. (In contrast, at land stations the day following a frontal passage usually provides extreme temperatures.) The standard deviation of the distribution is 4.6°F. and out of the

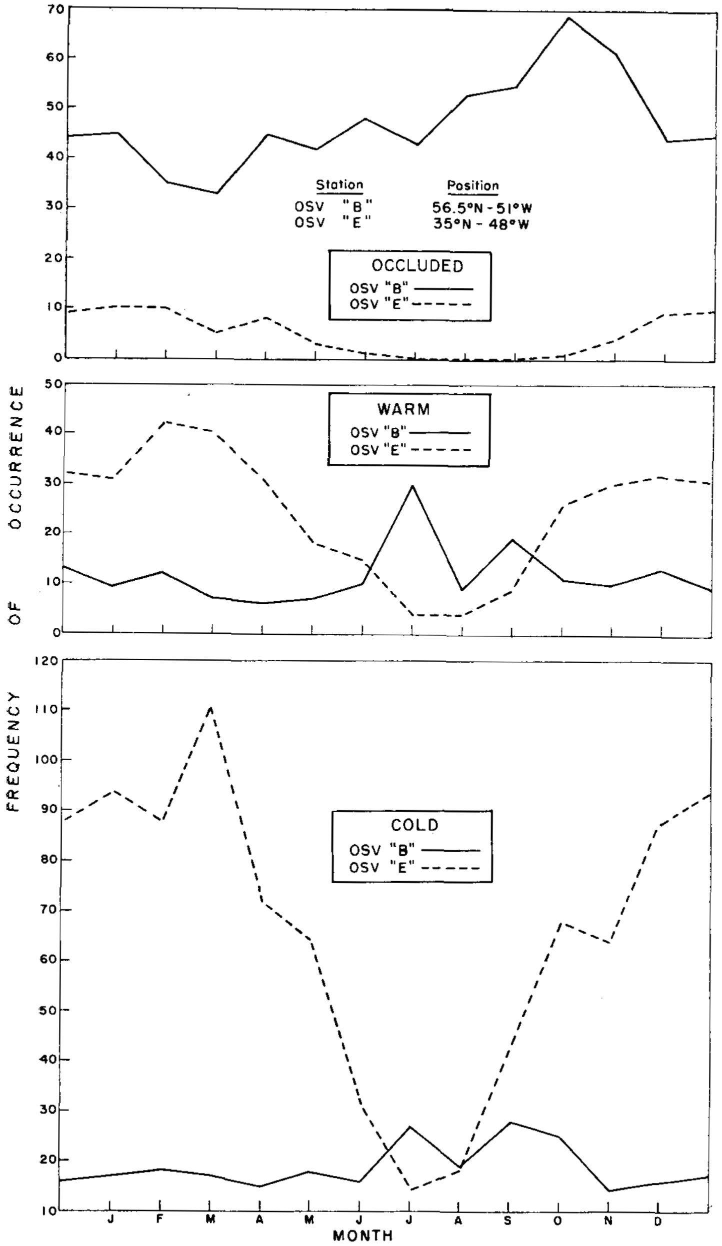

Figure 4.—Comparison of frequency of frontal passages at westernmost North Atlantic Ocean Station Vessels at high and low latitude for the period October 1945–June 1957.

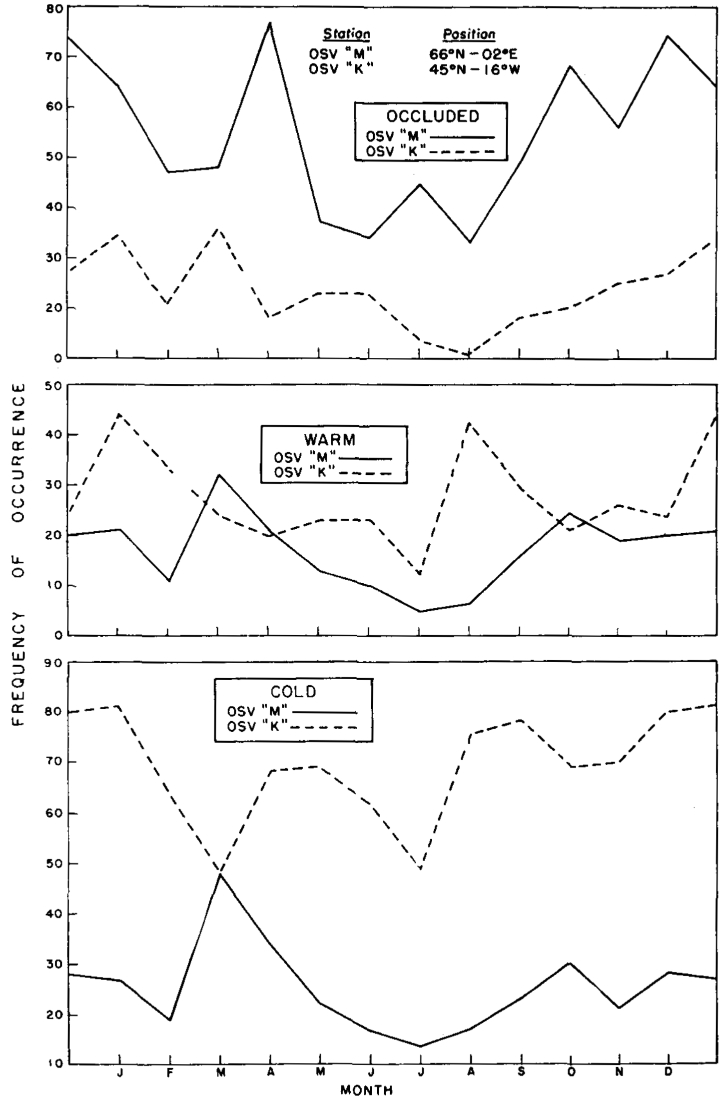

Figure 5.—Comparison of frequency of frontal passages at easternmost North Atlantic Ocean Station Vessels at high and low latitude for the period October 1945–June 1957.

sample of 6,820 frontal occurrences 5,049 of the 48-hour temperature changes fall within one standard deviation from the mean and 6,422 within two standard deviations. This indicates the effectiveness of the heat storage in the oceans in contrast to shallow heating and quick loss of heat by land masses. The same general results would be obtained with any single frontal type. Figure 7 gives a comparison of Stations "A" on the east of the southern tip of Greenland and "B" on the west against the most southern station, "E". Both of the northern stations, even though situated in the Labrador Current, demonstrate the profound and far-reaching influence of the Gulf Stream.

5. CONCLUDING REMARKS

This paper has presented a few basic statistics on frontal passages over an ocean area frequently traversed by both ships and aircraft. The data were compiled from synoptic weather maps, which are used rather infrequently as a source for climatological summarization.

This effort has demonstrated the degree of facility with which historical sea level synoptic maps may be used to determine a preliminary climatology of well-known features of atmospheric motion systems. It is hoped that it will direct some further thinking toward a useful climatology of dynamic systems in the general circulation.

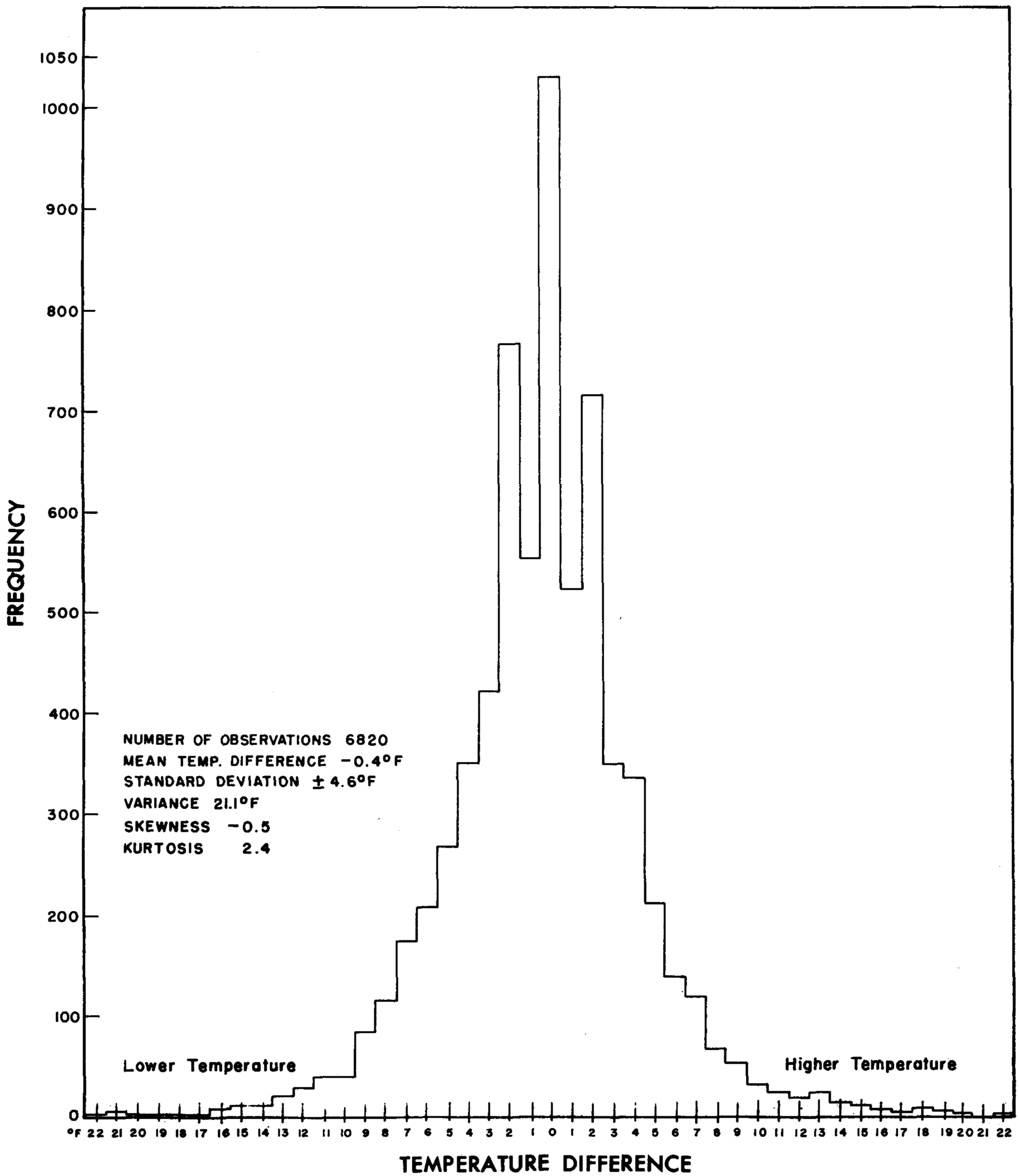

FIGURE 6.—Frequency of 48-hour temperature changes from 1230 GMT on day before to 1230 GMT on day after frontal passage for all North Atlantic Ocean Station Vessels. Temperature data for cold, warm, occluded, and stationary fronts are combined for all stations for the period October 1945–June 1957.

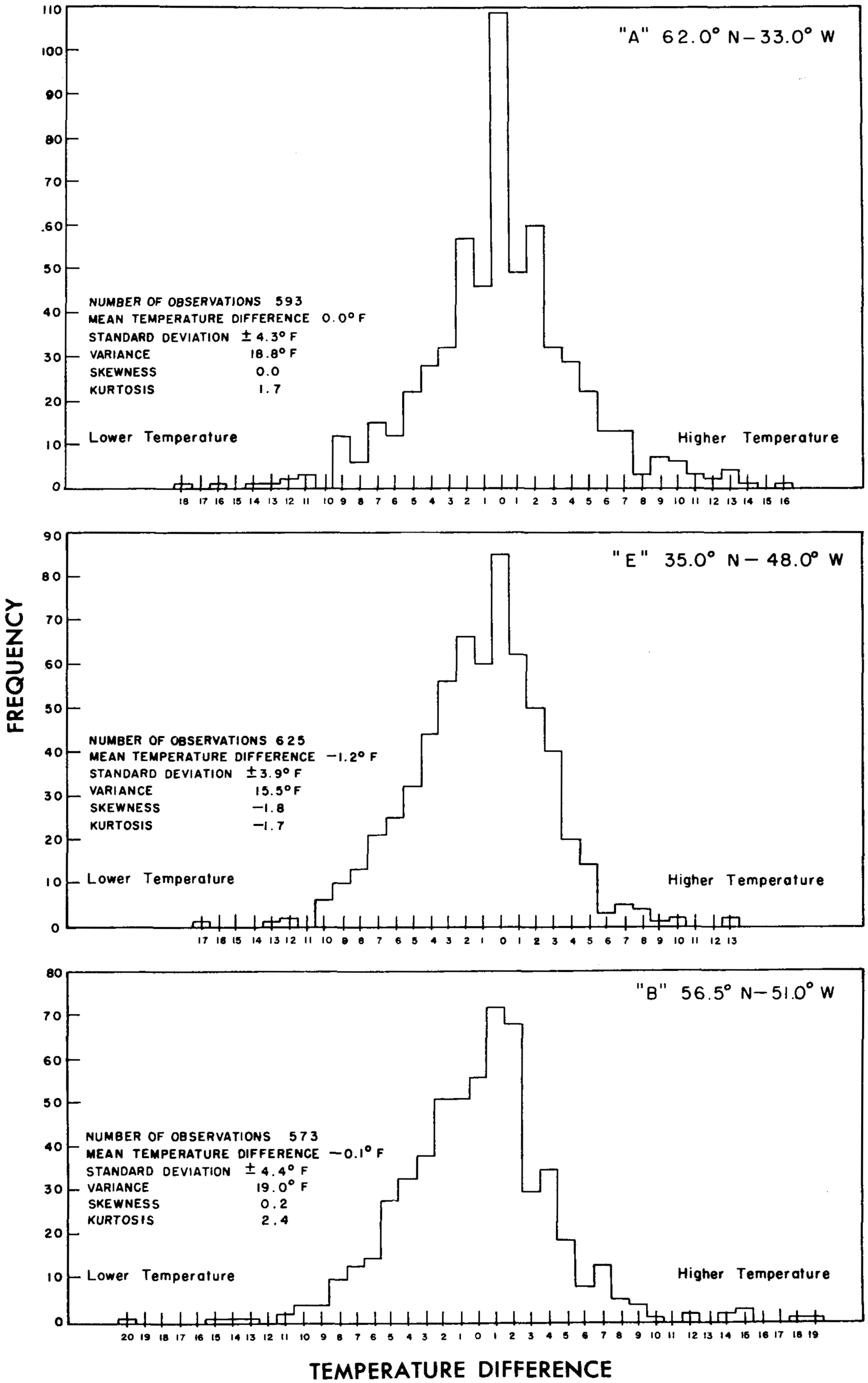

Figure 7.—Frequency of 48-hour temperature changes from 1230 GMT on day before to 1230 GMT on day after frontal passage at North Atlantic Ocean Station Vessels "A," "B," and "E." Temperature data for cold, warm, occluded, and stationary fronts are combined for the period October 1945–June 1957.

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NEW WEATHER BUREAU PUBLICATION

Technical Paper No. 37, "Evaporation Maps for the United States," Washington, D.C., 1959, 13 pp., 5 plates; for sale by Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Price, 65 cents.

The following information is presented by chart for the United States excluding Hawaii and Alaska: (1) average annual Class A pan evaporation, (2) average annual lake evaporation, (3) average annual Class A pan coefficient, (4) average May–October evaporation in percent of annual, and (5) standard deviation of annual Class A pan evaporation.